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APPLICATION FOR UNITED STATES LETTERS PATENT

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TITLE: MULTI-STEP POLISHING SYSTEM AND PROCESS OF USING SAME

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MULTI-STEP POLISHING SYSTEM AND PROCESS OF USING SAME

FIELD OF THE INVENTION

The present invention relates generally to the planarization of semiconductor workpieces, and more particularly, to a multi-step system and a process for polishing the workpieces using a oxidizer-free medium at one or more polishing stations.

BACKGROUND

Many steps in the manufacture of semiconductor devices produce a highly irregular surface on the front side of the wafer which contains the semiconductor devices. In order to improve the manufacturability of the devices on the wafer, many processing steps require planarizing the wafer surface. For example, to improve the uniformity of deposition of a metal interconnect layer, the wafer is planarized prior to deposition to reduce the peaks and valleys on the surface over which the metal is deposited.

In conventional planarization technology, a semiconductor wafer is supported face down against a moving polishing pad. Two types of polishing or planarizing apparatus are commonly used. In a rotary planarizing apparatus, a wafer is secured on a chuck and is brought into contact with a rotating polishing surface such as a circular disk. The rotating polishing surface may include a fixed abrasive for contacting and polishing the wafers, and/or a slurry having abrasives may be placed in contact with the polishing surface.

In a second type of planarization apparatus, utilizing linear planarization technology, an endless belt travels over two or more rollers. The wafer is placed against the linearly moving polishing surface of the belt. The belt may have an abrasive surface, and/or a slurry having abrasive particles may be placed in contact with the polishing belt. An example of such a system is the Teres™ CMP System manufactured by Lam Research Corporation, Fremont, California, aspects of which are disclosed in U.S. Pat.

Nos. 5,692,947, 5,762,536, and 5,871,390, and in commonly assigned co-pending U.S. App. Serial No. 08/968,333, entitled "Method and Apparatus for Polishing Semiconductor Wafers," filed November 12, 1997.

Many metallic materials are used to form the components of the semiconductor device. Because copper has high electrical conductivity and low electromigration suspectibility, copper metals, copper compounds, and copper metal-alloys are particularly well suited for forming integrated circuits on semiconductor wafers. As with any material used in semiconductor wafer fabrication, one important factor in forming narrow and precise components from a copper containing layer is the ability to begin the processing steps with a copper substance layer made uniform through the use of planarization.

One previous process for copper-containing surface planarization utilized a multi-step, multi-slurry approach. In the first step, large amounts of copper are removed in bulk, leaving a thin, relatively planar copper layer for the second step. In the second step, the copper is further planarized to leave a continuous barrier layer with minimal topography. In both the first step and the second step, an oxidizing slurry is used in conjunction with a polishing pad in order to soften the copper by first oxidizing the copper to copper oxide so that it can be more easily removed. In a final step, a rotary buffer is used to completely remove the barrier layer and leave clean, corrosion free copper and oxide surfaces.

It is important to have a stable, repeatable process so that a timed polish can be used. Bulk copper polishing removal rate stability is affected by a phenomenon known as pad loading. In standard oxide polishing, the removal rate stability is commonly affected by the polishing pad groove integrity. The removal rate stability tends to diminish as the grooves are worn down during the act of polishing and conditioning. In copper oxide polishing, however, the rate stability can deteriorate before the degradation of the pad grooves. The pad tends to load with a residue that reduces the ability of the pad to continue removing the copper oxide uniformly from the surface of the wafer. Various in-situ process changes, such as distilled water rinsing or chemical rinsing have been somewhat effective to combat the residue build-

up, but are impractical in large-scale fabrication processes. Furthermore, the frequent changing of a loaded pad is an unattractive option not only because of the expense of the pad, but also because of the down time to the fabrication equipment.

Accordingly, there is a need for an improved polishing process that prevents the build-up of residue in the polishing pad, thereby achieving a stable, repeatable planarization process.

SUMMARY

In one aspect of the invention, a wafer polishing process includes polishing a surface of a wafer in the presence of an oxidizer-free medium; and, subsequently, polishing the surface of the wafer in the presence of an oxidizing medium.

Other aspects of the invention will be apparent to those skilled in the art in view of the claims following the detailed description below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top schematic view of a system according to one embodiment of the present invention.

FIG. 2 is a exploded perspective view of a portion of the system of FIG. 1.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

The wafer polishing systems according to the present invention include one or more polishing stations. At one of the stations, a workpiece to be processed, such as a semiconductor wafer, is polished in the presence of an oxidizer-free medium. Then, subsequent to the oxidizer-free polishing, the wafer is polished with an oxidizing medium. The oxidizing polishing may occur at the same station or at a different station as the oxidizer-free polishing. This sequence of polishing helps to prevent the build-up of residues in the polishing pads, which not only extends the life of the polishing

pads, but also provides a more stable, uniform, and repeatable polishing process.

Referring now to FIGS. 1 and 2, a wafer polishing system according to one embodiment of the invention is shown generally at 10. The system 10 includes a first polishing station 20, a second polishing station 30, and a third polishing station 40. In the embodiment shown, the first polishing station 20 and the second polishing station 30 are each linear chemical-mechanical polishers, and the third polishing station 40 is a rotary chemical-mechanical polisher, such as a rotary buffer. A transfer mechanism 50 is adapted to move a workpiece, such as a wafer 60, successively from one station to the next. The system 10 shown in FIG. 1 is modeled generally on the Teres™ CMP System manufactured by Lam Research Corporation, Fremont, California, aspects of which are disclosed in U.S. Pat. Nos. 5,692,947, 5,762,536, and 5,871,390, and in commonly assigned U.S. App. Serial No. 08/968,333, entitled "Method and Apparatus for Polishing Semiconductor Wafers," filed November 12, 1997, all of which are incorporated by reference in their entireties. Those skilled in the art will appreciate that other polishing systems having one or more polishing stations may also be adapted in accordance with the present invention. For example, rotary polishing systems may be adapted in accordance with the present invention.

As shown in FIG. 2, the first polishing station 20 includes a workpiece holder 22, a polishing pad 24, and an inlet 26. The workpiece holder 22 secures a workpiece, such as a wafer, in a polishing portion 21 of the polishing station 20 defined generally by an area adjacent both the polishing pad 24 and the workpiece holder 22. The polishing station 20 is in communication via a delivery system 70 with a source 62 of an oxidizer-free medium, and with a source 64 of an oxidizing medium. The second polishing station 30 includes a workpiece holder 32, a polishing pad 34, and an inlet 36. The workpiece holder 32 secures a workpiece, such as a wafer, in a polishing portion 31 of the polishing station 30 defined generally by an area adjacent both the polishing pad 34 and the workpiece holder 32. The polishing station 30 is in communication via a delivery system 70 with the source 62 of

oxidizer-free medium and the source 64 of an oxidizing medium. The third polishing station 40 includes a workpiece holder 42 and a rotary pad 44.

The delivery system 70 is adapted to deliver the oxidizer-free medium and the oxidizing medium to the polishing stations 20, 30. In a preferred delivery system shown in FIG. 2, the delivery system 70 delivers either of the oxidizer or oxidizer-free media to either of the inlets 26, 36. The media may then be carried by the polishing pads 24, 34 to their respective polishing portions 21, 31. The delivery system 70 includes lines 71, such as conventional piping, a shut-off valve 72 for source 62, a shut-off valve 74 for source 64, and a pair of three-way valves 76, 78. By manipulating the valves 72, 74, 76, 78, either the oxidizer-free medium or the oxidizing medium may be delivered to either of the inlets 26, 36, of the polishing stations 20, 30. Those skilled in the art will appreciate that other combinations of medium sources and delivery systems may readily be used in conjunction with the present invention. For example, each polishing station may have its own separate pair of media sources. In another example, each station may have separate inlets for the oxidizing and oxidizer-free media, respectively.

In a process in accordance with the present invention, the transfer mechanism 50 first places a workpiece, such as a wafer, from a workpiece storage position 52 (FIG. 2) to a first position 54. As more thoroughly described in U.S. App. Ser. No. 08/968,333, the transfer mechanism 50 and the workpiece holder 22 interact to position a surface of the workpiece in the polishing portion 21 of the first polishing station 20. A oxidizer-free medium is then supplied to the polishing portion 21 via the delivery system 70 and the inlet 26. The surface of the workpiece is then polished at the first polishing station 20 in the presence of an oxidizer-free medium. Next, in one embodiment of the invention, the supply of oxidizer-free medium is discontinued, and an oxidizing medium is supplied to the polishing portion 21 via the delivery system 70 and the inlet 26. The surface of the workpiece is then polished in the presence of the oxidizing medium.

In an alternate embodiment, after the polishing in the presence of an oxidizer free medium at the first polishing station 20, the transfer mechanism

50 transfers the workpiece to a second polishing position, and the transfer mechanism 50 and the workpiece holder 32 cooperate to position a surface of the workpiece in the polishing portion 31 of the polishing station 30. The surface of the workpiece is then polished at the second polishing station 30 in the presence of an oxidizing medium supplied from the source 38 via delivery system 70 and the inlet 36.

The transfer mechanism 50 then moves the workpiece to a third position 58, and the workpiece holder 42 and the transfer mechanism 50 cooperate to position a surface of the workpiece adjacent a surface of the polishing pad 44. The surface of the workpiece is then polished at the third polishing station 40.

Other system arrangements and sequences may also be useful in the practice of the present invention. For example, a system may have multiple polishing stations using an oxidizer-free medium before the workpiece is transferred to a polishing station using an oxidizing medium. In another example, an oxidizing medium may be used at multiple polishing stations that are subsequent to at least one polishing station which uses an oxidizer-free medium. In other examples, the media are used at a polishing station having a rotary polisher rather than a linear polisher. In all such embodiments according to the present invention, a workpiece is polished on at least one polishing station using an oxidizing-free medium before it is polished at the first of the polishing stations that uses an oxidizing medium.

In the preferred embodiment of the invention, the workpiece is a semiconductor wafer, and the surface to be polished has a metallic component. In an especially preferred embodiment of the invention, the surface to be polished includes copper-containing components, such as copper metals, copper compounds or copper metal alloys. In other embodiments of the invention, the surface to be polished is aluminum, tungsten, tungsten silicide, titanium nitride, tantalum, or other materials capable of undergoing oxidation and that are commonly used in semiconductors.

As used herein, the term "oxidizer-free medium" means a medium that contains no components in a concentration sufficient to substantially raise the oxidation state of the target surface material to be polished. Conversely, the term "oxidizing medium" means a medium than contains at least one component in a concentration sufficient to substantially raise the oxidation state of the target surface material to be polished. The classification of a medium thus will be dependent upon the identity of the surface being polished.

Oxidizing agents and oxidizing medium are well-known in the semiconductor processing art. For example, common oxidizing agents for copper containing surfaces include nitric acid, potassium permanganate, hypochlorous acid, acetic acid, sulfuric acid, silver nitrate, copper sulfate, and copper perchlorate. Common oxidizing agents for tungsten surfaces include potassium ferricyanide, potassium dichromate, potassium iodate, potassium bromate, vanadium trioxide, cerium nitrate, and ferrous nitrate. Common oxidizing agents generally include those that have peroxoy groups, such as hydrogen peroxide, organic peroxides such as benzyl peroxide, peracetic acid, di-t-butyl peroxide, monopersulfates, dipersulfates, and sodium peroxide; and compounds containing elements in their highest oxidation state, such periodic acid, periodate salts, perbromic acid, perbromate salts, perchloric acid, perchloric salts, perboric acid, and perborate salts and permanganates; bromates, chlorates, chromates, iodates, iodic acid, and cerium (IV) compounds, such as ammonium cerium nitrate.

Both the oxidizing media and the oxidizer-free media are preferably slurries having abrasive particles. In an alternate embodiment, the media are fluids without abrasive particles. In this alternate embodiment, it is preferred to use polishing pads that have fixed abrasives. Examples of suitable pads having fixed abrasives are disclosed in U.S. App. Ser. No. 09/540,810, entitled "Fixed Abrasive Linear Polishing Belt and System," filed on March 31, 2000, which is incorporated herein by reference. In other embodiments, the polishing may proceed without the use of any abrasives.

Those skilled in the art will recognize abrasive components useful with the present invention. Preferred abrasive components include alumina, silica, ceria, and iron oxide. In the embodiments where abrasive slurries are used, the slurries are preferably about 1 wt % to about 25 wt % abrasive material, more preferably about 2 to 15 wt % abrasive material, and more preferably about 5 wt % abrasive material. Preferred abrasives will have a hardness of about Mohs 5 to Mohs 6, and a particle size of about 0.01 microns to about 0.5 microns, and more preferably, about 0.05 microns to about 0.3 microns.

The media of the present invention may optionally contain a film-forming agent. Common film-forming agents include benzotriazole, urea, thiourea, and cyclic compounds, such as imidazole, benzimidazole, benzothiazole and their derivatives. The film-forming agent is preferably present at about 0.01 wt % to 1.0 wt % of the medium, and more preferably, at about 0.01 to 0.2 wt %.

Numerous other additives may be included in both the oxidizing and oxidizer-free media, including complexing or chelating agents (such as glycine), surfactants (such as dodecyl sulfate sodium salt, sodium lauryl sulfate, or dodecyl sulfate ammonium sulfate), and complexing agents to disturb the passivation layer (such as citric, lactic, tartaric, succinic, acetic, or oxalic acids).

In a preferred embodiment of the invention, an oxidizer-free slurry includes about 3 to about 25 wt %, and more particularly, about 8 to about 15 wt % of an abrasive, such as alumina; about 0.5. to 2 wt %, and more particularly, about a 1 wt % of a complexing or chelating agent, such as glycine; about 0.01 to about 1.0 wt %, and more particularly, about 0.05 wt % of a film-forming agent, such as benzotriazole; and about 78 to about 96 wt %, and more particularly, about 88 to about 92 wt % of a solvent, such as water or an alcohol. In a particularly preferred embodiment of the invention, the oxidizer-free medium is Cabot EPC 5001, sold by Cabot Microelectronics of Aurora, Illinois. In a preferred embodiment, the oxidizing slurry has the same composition as the oxidizing-free slurry, except that it also includes about 1 to

about 10 wt %, and more particularly, about 3 wt % of an oxidizing agent, such as hydrogen peroxide.

Suitable polishing pads for use with the present invention are those typically used in the art for chemical-mechanical polishing. Suitable rotary pads include the Rodel Embossed Politex sold by Rodel Corporation of Phoenix, Arizona. Suitable linear polishing pads include IC-1000, also sold by Rodel, as well as those disclosed in U.S. App. Serial No. 09/386,741, entitled "Unsupported Chemical Mechanical Polishing Belt," filed August 31, 1999, and in U.S. App. Ser. No. 09/540,810, entitled "Fixed Abrasive Linear Polishing Belt and System," filed on March 31, 2000, both of which are incorporated herein by reference. Suitable addition rates for both the oxidizer-free and oxidizing media are about 500 ml/min, and more preferably, about 50 to about 200 ml/min.

It should be readily understood by those persons skilled in the art that the present invention is susceptible of a broad utility and application. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements will be apparent from or reasonably suggested by the present invention and the foregoing description thereof, without departing from the substance or scope of the present invention.

Accordingly, while the present invention has been described herein in detail in relation to several embodiments, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purposes of providing a full and enabling disclosure of the invention. The foregoing disclosure is not intended or to be construed to limit the present invention or otherwise to exclude any such other embodiments, adaptations, variations, modifications and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.